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ORIGINAL ARTICLE

# Magnetic resonance imaging versus Ultrasound examination in detection of prenatal fetal brain anomalies

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## KEYWORDS

Magnetic resonance imaging;  
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2D and 4D ultrasound

**Abstract** *Purpose:* Evaluation of the role of MR Imaging in detection of fetal brain anomalies versus 2D and 4D Ultrasound examination.

*Study design:* This study included 23 pregnant females who were suspected to have fetus with congenital brain anomalies over a period of one year using ultrasound. MRI was done within one week following 2D and 4D US examination. The maternal age ranged from 18 to 39 years. The gestational age ranged from 16 to 36 weeks (mean age = 26 weeks). Antenatal Ultrasound and magnetic resonance findings were compared with postnatal MRI findings.

*Results:* We reported different types of congenital brain anomalies including eight cases of isolated central nervous system anomalies. MRI and ultrasound showed concordant findings in six cases. MRI changed the diagnosis in 14 cases and provided additional information in two cases. Ultrasound was superior to magnetic resonance imaging in one case at second trimester due to fetal motion.

*Conclusion:* Our results showed that fetal MR imaging is useful in detection of fetal central nervous system anomalies as well as a complementary modality to 2D/4D Ultrasound in diagnosis of fetal central nervous system anomalies.

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## 1. Introduction

Congenital malformation is a stimulating problem for research study because of the high frequency of its occurrence and the devastating effect it may have on the individual and his family. Considerable variations in frequency in different populations have been reported, from as low as 1.07% in Japan (1) to as high as 4.3% in Taiwan (2). In Egypt, the following results have been reported: 1.16% in Alexandria University Hospital (3), 1.58% in Ain Shams University Hospital (4).

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**Table 1** Comparative study between 2/4D US and prenatal MR imaging of fetal CNS anomalies.

NO.	Maternal age/years	Fetal age/weeks	Prenatal US	Prenatal MRI	Postnatal MRI	Postnatal Anomaly	Comment
1.	23	21	Ventriculomegaly	Ventriculomegaly	Ventriculomegaly	Ventriculomegaly	Same
2.	34	25	Ventriculomegaly	Ventriculomegaly	Ventriculomegaly	Ventriculomegaly	Same
3.	25	18	Ventriculomegaly	Obstructive hydrocephalus resulting from intracranial lesion showing some cystic changes	Obstructive hydrocephalus resulting from intracranial lesion showing some cystic changes	Obstructive hydrocephalus resulting from intracranial lesion showing some cystic change	Additional information by MRI
4.	29	32	Mild ventriculomegaly	Mild ventriculomegaly	Normal	Normal	Change
5.	35	33	Giant cisterna magna	Giant cisterna magna	Giant cisterna magna	Giant cisterna magna	Same
6.	19	21	Missed	Giant cisterna magna	Giant cisterna magna	Giant cisterna magna	Missed by US, but diagnosed by MRI
7.	18	17	Missed	Giant cisterna magna	Giant cisterna magna	Giant cisterna magna	Missed by US, but diagnosed by MRI
8.	37	28	Missed	Hydrencephaly	MRI, was not done due to termination of pregnancy ,autopsy	Hydrencephaly	Missed by US, but diagnosed by MRI
9.	27	23	Hydrocephalus	Hydrencephaly	MRI, was not done due to termination of pregnancy	Hydrencephaly	Missed by US, but diagnosed by MRI
10.	39	36	Missed	Hydrencephaly	MRI, was not done due to termination of pregnancy	Hydrencephaly	Missed by US, but diagnosed by MRI
11.	25	32	Acrania	Acrania	MRI, was not done due to termination of pregnancy	Acrania	Same
12.	30	26	Anencephaly	Anencephaly	MRI, was not done due to termination of pregnancy	Anencephaly	Same
13.	32	16	Anencephaly	Missed	MRI, was not done due to termination of pregnancy	Anencephaly	Missed by prenatal MRI
14.	31	22	Enlarged cisterna magna and ventriculomegaly	Dandy walker	Dandy walker	Dandy walker	Change
15.	27	26	Enlarged cisterna magna	Dandy walker	Dandy walker	Dandy walker	Change of diagnosis
16.	33	32	Cystic lesion in the posterior fossa	Dandy walker	Dandy walker	Dandy walker	Change of diagnosis
17.	35	36	Hydrocephalus	Large arachnoid cyst	Large arachnoid cyst	Large arachnoid cyst	Change of diagnosis
18.	19	30	Hydrocephalus	Agenesis of the Corpus callosum Large arachnoid cyst	Agenesis of the Corpus callosum Large arachnoid cyst	Large arachnoid cyst	Change of diagnosis
19.	26	28	Holoprosencephaly	Large arachnoid cyst	Large arachnoid cyst	Large arachnoid cyst	Change of diagnosis
20.	29	35	Intraventricular cyst	Agenesis of the Corpus callosum Porencephalic cyst	Agenesis of the Corpus callosum Porencephalic cyst	Large arachnoid cyst Agensis of the Corpus callosum Porencephalic cyst	Additional information
21.	30	29	Hydrocephalus	Interhemispheric cyst	Interhemispheric cyst	Interhemispheric cyst	Change of diagnosis
22.	35	34	Holoprosencephaly	Holoprosencephaly	Termination of pregnancy	Holoprosencephaly	Same diagnosis
23.	24	19	Hydrocephalus	Holoprosencephaly	Termination of pregnancy	Holoprosencephaly	Change of diagnosis

A study conducted in Giza, Egypt on 3,000 live and still-birth babies, showed that 3.17% (95 babies) had congenital anomalies, the commonest being CNS anomalies constituting about 1/3 of all malformations (5). Central nervous system abnormalities affect approximately 6,000 neonates each year in the USA (6).

Prenatal diagnosis of congenital anomalies is a difficult problem to which ultrasound has made substantial contributions. The availability of a relatively safe, independent technique would represent a welcome clinical and research alternative in the evaluation of fetal abnormalities (7).

Ultrasound is the primary modality used to assess the fetus. This examination by a skilled operator, in most cases, provides adequate information regarding fetal morphology, its environment, and its well-being. The quality of Ultrasound however, is adversely affected by factors such as maternal obesity, unfavorable fetal position, multiple gestations, decreased amniotic fluid or the near-field reverberation artifact (8).

The abnormalities detected on Ultrasound may at times be very subtle or inconclusive. In such cases, several studies have shown that MRI is a helpful modality (7,9,10).

Magnetic resonance imaging (MRI), provides a highly accurate depiction of the morphological changes of development in the normal brain and in fetal brain disorders. Thus, MRI can provide improved anatomical resolution. Another advantage of MRI is that intracranial brain imaging is not impacted by the calvaria, which allows clear identification of the cortex and subarachnoid space (11,12).

This study, describes the ideal timing of the MRI examination, safety issues, technique and various indications illustrated and explained by typical examples and cases.

Moreover, prenatal US has a limited specificity in diagnosis of fetal anomalies. For example, ventriculomegaly is a common end point for various pathologic processes including hydrocephalus, cerebral dysgenesis, and atrophy or encephalomalacia. Differential diagnosis in such cases is important (13,14).

The potential application of MRI as an alternative to Ultrasound has its advantages and limitations (15). Fetal motion was a limiting factor in early studies however; the fast MRI sequences can obtain images in just 430 ms and subse-

quently can obtain images required for diagnosis. Real time MRI allows almost continuous imaging of the moving fetus (15,16).

MRI is a useful supplement to Ultrasound for the assessment of fetal brain malformations. Superior soft tissue contrast and the ability to depict sulcation and myelination are the strengths of MRI. Subtle or inconclusive Ultrasound abnormalities can be confirmed or ruled out by MRI. In some cases, additional findings detected with MRI often help in arriving at a definitive diagnosis, which is necessary for parental counseling and for guiding management. Fast T2W sequences form the basis of fetal MRI. There have been no reports of deleterious effects of MRI on the fetus (8).

## 2. Materials and methods

This study had been carried out over a period of one year duration (from April/2010 to April/2011) between Radio diagnosis and Obstetrics and Gynecology departments, Tanta University, Egypt.

One thousand hundred five pregnant women were enrolled in the study; only Twenty-three pregnant women were referred from the obstetrics and Gynecology Department suspected to have fetal CNS anomalies. All cases were examined by 2D and 4D ultrasound and underwent MR imaging within one week. The mean fetal gestational age was  $26 \pm 10$  weeks (ranged from 16 to 36 weeks). Results were reviewed and compared by two radiologists.

Postnatal physical examination and postnatal MR imaging results were the gold standard for the evaluation of the accuracy of either modality.

### 2.1. Inclusion criteria

All pregnant women suspected by 2D and 4D ultrasound to have fetal CNS anomalies.

### 2.2. Exclusion criteria

Patients contraindicated for MRI examination (cardiac pacemaker).

**Table 2** Comparison between 2D/4D US and prenatal MRI in detection of prenatal congenital CNS anomalies.

	Postnatal anomalies ( $N = 23$ )				Total
	(Postnatal MRI ( $n = 17$ ) & autopsy ( $n = 6$ ))				
	+ VE	+ VE %	−VE	−VE %	
2D-4D prenatal US	7	30.4%	16	69.6%	23
MRI prenatal	21	91.3%	2	8.7%	23
$P$	$P > 0.0001$		$p > 0.0001$		

**Table 3** Sensitivity, specificity, positive predictive value and negative predictive value for 2/4D U/S and MRI in detection of prenatal congenital CNS anomalies.

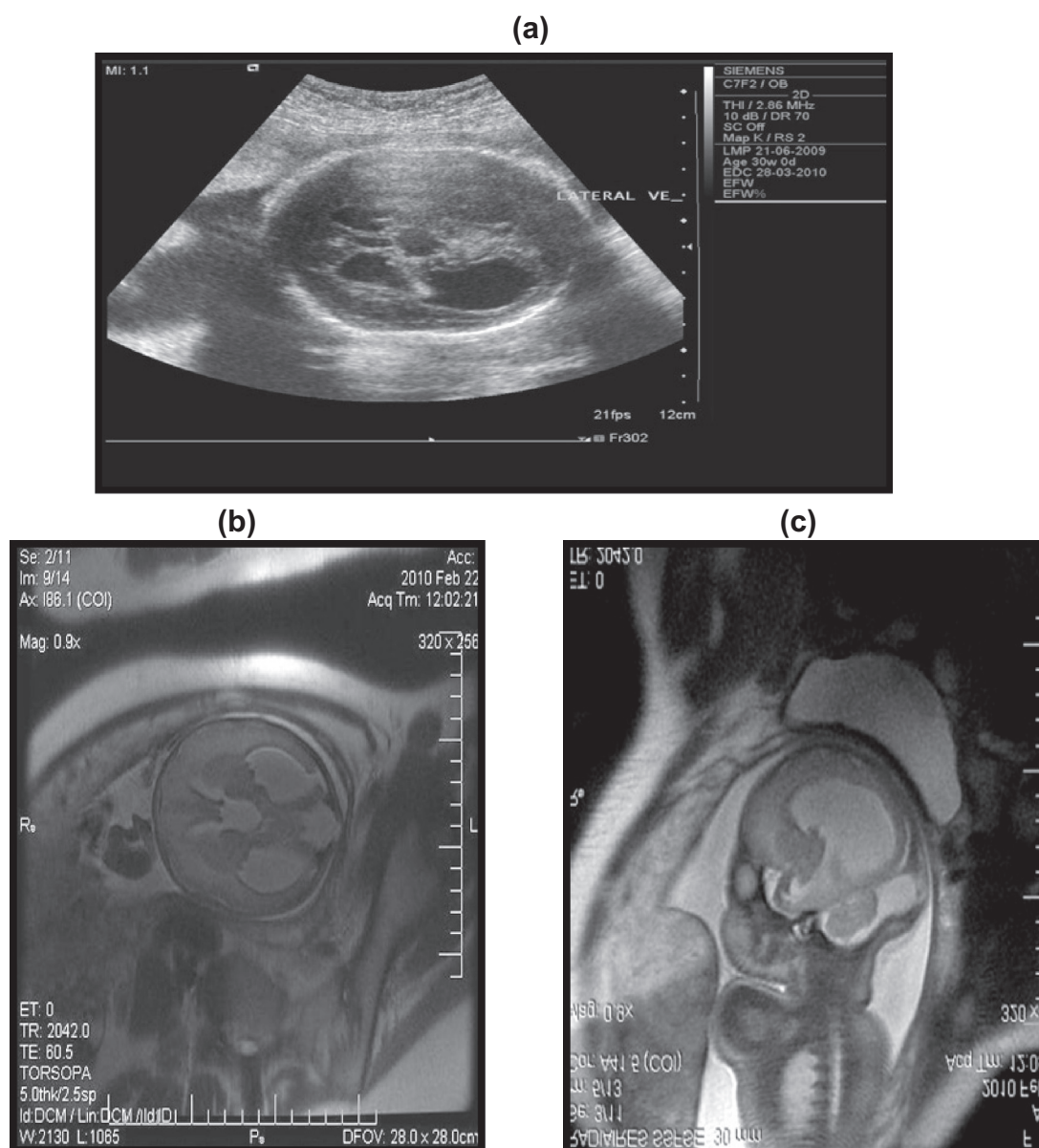
	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
2\4D prenatal US	30	99.8	87.5	98.4
MRI prenatal	91	100	100	100

### 2.3. Patients underwent the following

- 1- Thorough medical history taking.
- 2- Full clinical examination.
- 3- Two dimension and four dimension ultrasound examination done using sonoline-Antares machine (Siemens) using probe C5 (obstetric probe & CX 5-2 4D probe).
- 4- Prenatal MR imaging was performed using 1.5 Tesla machine (General Electric, High speed Signa) without maternal sedation. Mothers fasted 4 h before the examination to reduce bowel peristalsis and to reduce post-prandial fetal motion. They were asked to empty the urinary bladder prior to the examination. They were made to lie supine during the examination. They were

also examined in the left lateral decubitus position in some cases when the examination was uncomfortable for them. MR imaging was primarily performed, using initial three plane localizer with single shot fast spin echo (TR 4960-TE 100 band width 50) to visualize the position of the fetus. Then neuroimaging examination was done for fetal brain imaging (axial, sagittal and coronal plane).

Fetuses were imaged with FIESTA and Single Shot Fast Spin Echo T2 weighted sequence (TR 4475, TE 102, band width 31, freq 384 and phase 320) T1 weighted sequence (TR 550, TE 10, band width 28, freq 320 and phase 224). Ventriculomegaly on fetal MRI was defined if the size of the atrium of the lateral ventricle exceeds 10 mm.



**Fig. 1** Case (1) diagnosed by ultrasonography (a) just hydrocephalic changes MRI (axial (b) and sagittal (c) cuts) show dilation of supratentorial ventricular system with direct communication of 4th ventricle with retro cerebellar CSF space and both cerebellar atrophic change.



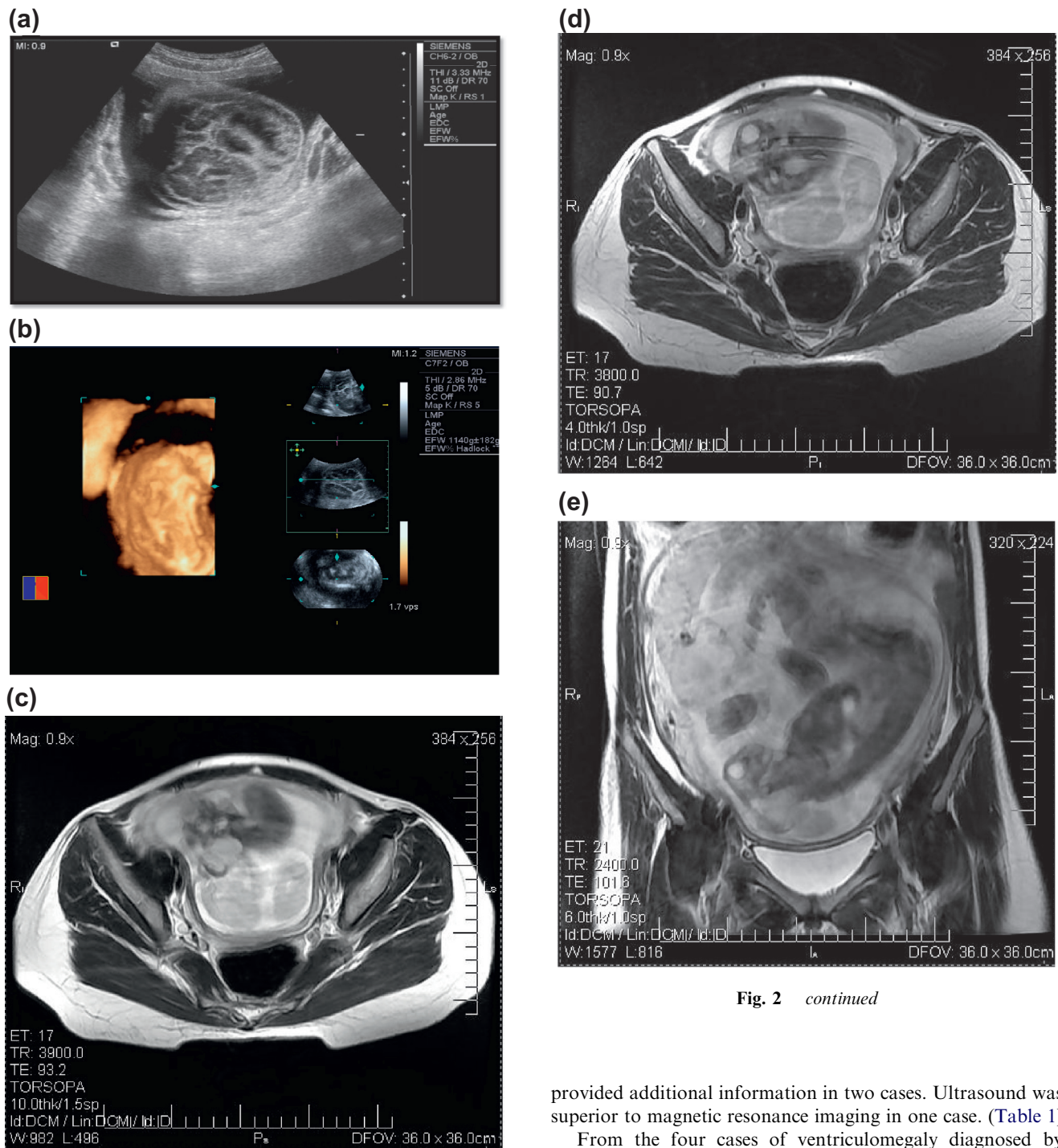


Fig. 2 continued

**Fig. 2** Both 2D (a) & 4D (b) US and MRI (c and d) axial cut (e) sagittal cut show anencephaly with no skull vault seen.

Postnatal MR imaging was performed to baby in 17 cases and autopsy done in six cases.

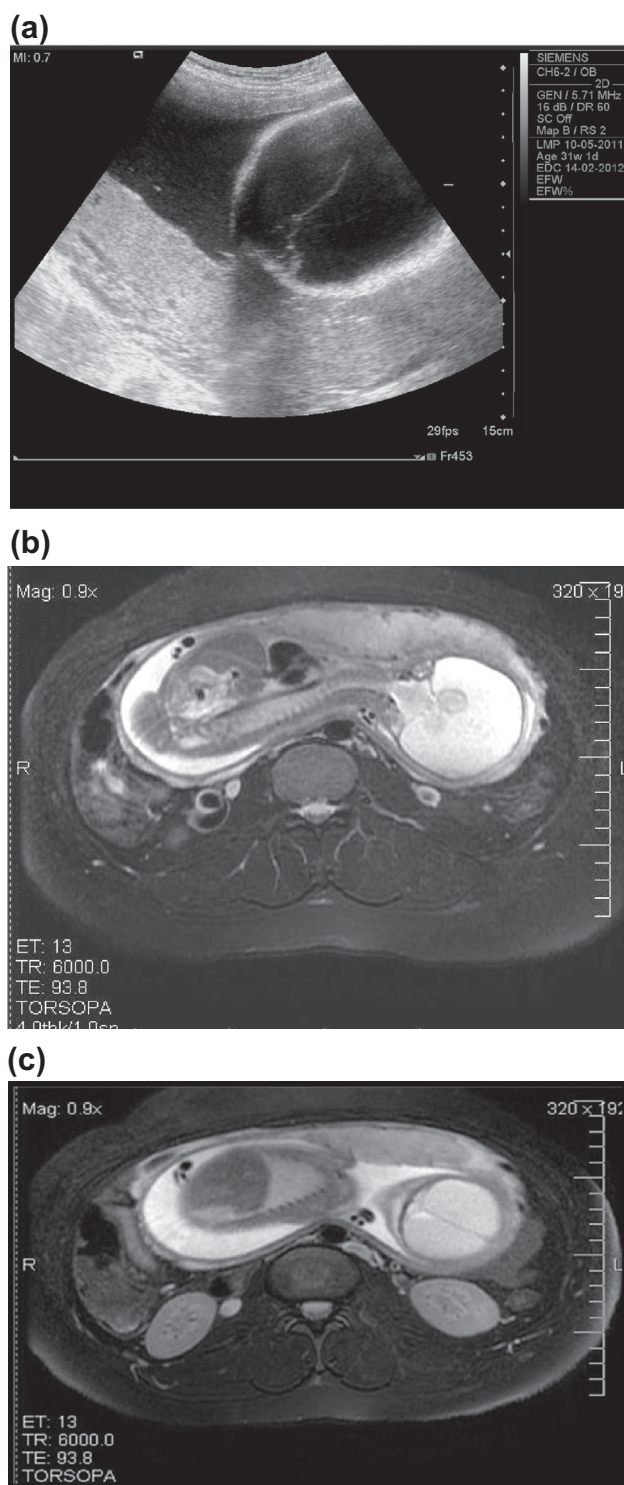
### 3. Results

In this study we reported different types of brain congenital anomalies. MRI and ultrasound showed concordant findings in six cases. MRI changed the diagnosis in 14 cases and

provided additional information in two cases. Ultrasound was superior to magnetic resonance imaging in one case. (Table 1)

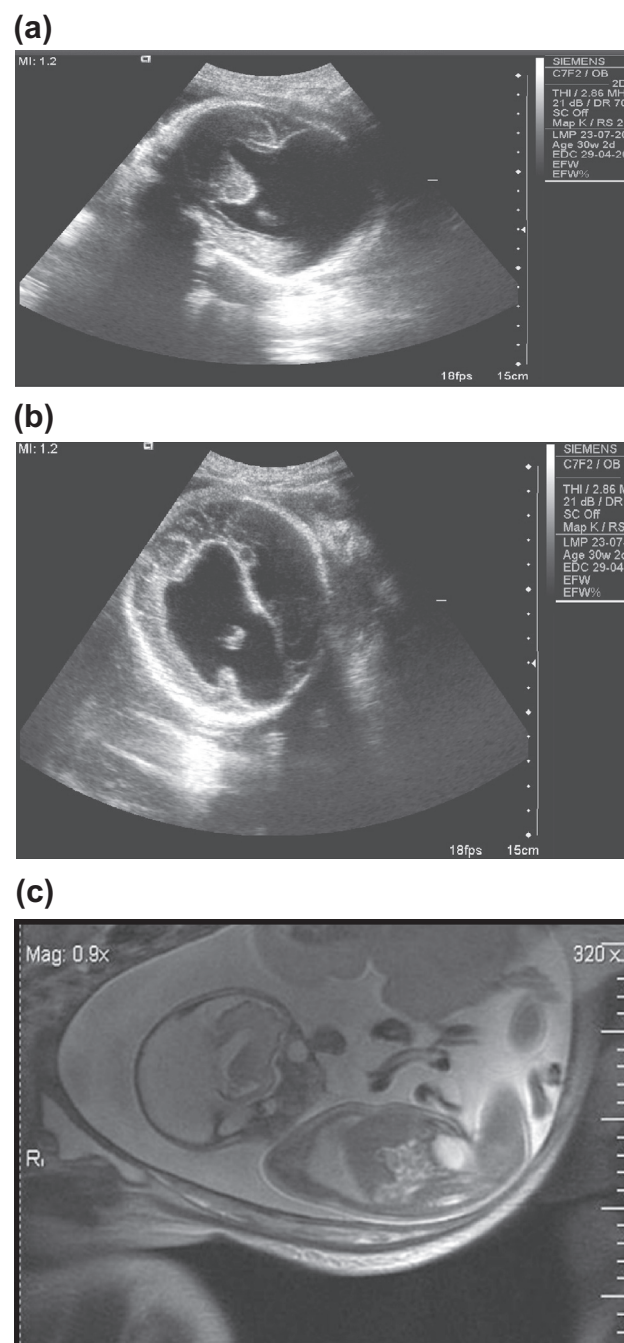
From the four cases of ventriculomegaly diagnosed by Ultrasound we got additional information, in one case, by MRI in degree and cause of ventriculomegaly. In this case, prenatal MRI showed obstructive hydrocephalus resulting from intracranial cystic lesion. This was confirmed by post natal MRI. This additional information was important in management plan and prognosis of the fetus. Postnatal surgical interference was performed.

Ultrasound was superior to MRI in early diagnosis of anencephaly as we performed MRI for two cases of anencephaly and one case of acrania (exococephaly) diagnosed by Ultrasound between 16 and 32 weeks of gestation. Prenatal MRI was able to diagnose two of the three cases and the diagnosis in the third case was not confirmed till 20 weeks of gestation.



**Fig. 3** US (a) show cystic changes of the brain with slight turbidity, diagnosed as marked hydrocephalic changes \ MRI (b and c) show normal size ventricular system with complete damage of the brain mantle and replaced by turbid cystic fluid, falx is seen —diagnosed as hydrencephaly.

In this study, we got three cases of Giant cisterna magna based on Prenatal MRI. The first case was suspected by Ultrasound and the other two cases were not detected by Ultrasound and were referred to do MRI because of other



**Fig. 4** US (2D) (a and b) diagnosed as asymmetry dilation of the supra tentorial ventricular system MRI (c-e) show large intra-hemispheric cyst communicate with left lateral ventricle.

suspected anomalies in the GIT and the Thorax. The three cases of Giant cisterna magna were confirmed by postnatal MRI.

MRI was also able to diagnose hydrencephaly, an anomaly which could not be detected by Ultrasound in this study. In one of these cases, the mother underwent MRI upon her request because of positive family history of congenital anomalies. The second case underwent MRI for assessment of complex ovarian mass during pregnancy and hydrencephaly



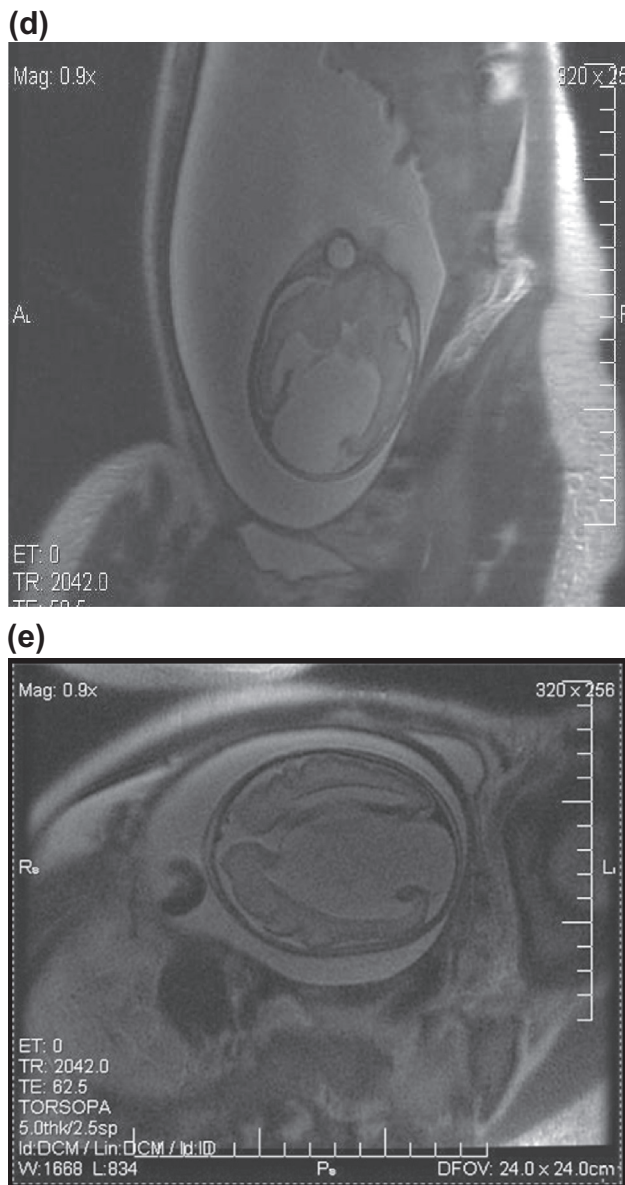


Fig. 4 continued

was found incidentally. For the third case, hydrencephaly was diagnosed as hydrocephalus.

In this study MRI changed the diagnosis in three cases. The first two cases were referred for MRI because of Ultrasound findings of enlarged cisterna magna and ventriculomegaly, and cystic lesion in the posterior fossa in the other case. The three cases were diagnosed as Dandy walker on Prenatal MRI and confirmed later by postnatal MRI.

In this study, we got three cases of arachnoid cyst by prenatal MRI however, prenatal Ultrasound diagnosed two cases as hydrocephalic changes and one as holoprosencephaly.

Moreover, two cases were diagnosed by prenatal US as intraventricular cyst. The diagnosis on prenatal MRI was a large interhemispheric cyst and agenesis of the Corpus callosum in one case and large porencephalic cyst in the other case. The diagnoses were confirmed by Postnatal MRI.

The anomaly of holoprosencephaly was detected twice in our study on prenatal MRI. The diagnosis was concordant by both Ultrasound and prenatal MRI in one case while in the second case, the Ultrasound diagnosis was hydrocephalus. Holoprosencephaly was confirmed by Postnatal MRI.

In Table 2: seven of 23 cases were diagnosed by 2D and 4D US (about 30.7%) while MRI provided additional information and confirmed diagnosis in 21 of 23 cases (91.3%;  $P > 0.0001$ ), 2D and 4D US failed to diagnose 16 cases (69.3%) while MRI failed in two cases (8.7% -  $P > 0.0001$ ).

In this study 2/4D US showed sensitivity, specificity, PPV and NPV (30%, 99.8%, 87% and 98.4%, respectively) while, MRI showed sensitivity 91% and 100% for specificity, PPV and NPV (Table 3) (Figs. 1–4).

#### 4. Discussion

Prenatal 2D/4D Ultrasound is an effective modality in detection of CNS anomalies and their management. However, Ultrasound evaluation of the fetal central nervous system is limited by the non specific ultrasound appearance of some anomalies and technical factors that make visualization of the brain near the transducer difficult (7).

Alternative imaging modality is needed in cases in which ultrasound diagnosis is difficult e.g. holoprosencephaly (17).

Fetal MRI can provide useful information that ultrasound cannot provide for making therapeutic plan (17).

The effectiveness of fetal MRI as an optional modality for detecting fetal abnormalities, which was well known, was reaffirmed by this study.

In our study 6 out of 23 cases of fetal brain anomalies were confirmed by both ultrasound and prenatal MRI. The final diagnosis was changed after fetal MRI in 14 cases. Moreover in two cases MRI provided additional information to that obtained by Ultrasound examination.

Our study coincided with Yong seak et al. (17) that fetal MRI has an advantage over Ultrasound in evaluation and detection of posterior fossa abnormalities, causes of ventriculomegaly, intracranial abnormalities and brain atrophy, this was also confirmed by Blaicher et al. (18).

In our study, the fetuses with callosal anomalies were not diagnosed on ultrasound and were diagnosed as abnormal configuration of both lateral ventricles, while with MR imaging, callosal anomalies can be diagnosed clearly as the corpus callosum can be seen directly. These findings coincide with Kier et al. (19).

In our study, fetal MRI was helpful in evaluating abnormalities of the posterior fossa which includes dandy walker and Giant cisterna magna which are difficult to be diagnosed by ultrasound alone and this was in agreement with other studies (20,24).

Although US provides abundant information in evaluating fetal structure abnormalities and fetal well being, US findings are occasionally inconclusive or insufficient for choosing proper management and prenatal counseling. In these cases alternative imaging with MRI can be helpful. MR imaging most likely can be useful as a secondary technique to confirm fetal abnormalities. Advantage of MR includes multiplanar tissue contrast and a large field of view. Disadvantage includes expense and long imaging times. This was agreed by Robert et al. (25,26).

Also with MRI, visualization of the fetuses has been limited by fetal motion and these were clear in cases of anencephaly which was failed to be diagnosed by MRI in our study in

one case due to fast fetal movements and early gestational age. This was confirmed in other studies (27,29). The case of late pregnancy and relative decrease in AF amount with a decrease of fetal movements and motion artifact will improve fetal visualization, this coincides with other studies (30,31).

Lastly in this study we suggest that fetal MRI is useful for the evaluation of intracranial abnormalities especially when ultrasound questionable anomalies are seen or when an abnormality is definite but the exact diagnosis was uncertain.

Fetal MRI can confirm suspicious ultrasound findings and thus add confidence in a particular prenatal diagnosis before performing invasive and interventional procedures. The ultrasound can evaluate very small structures that complement the lower resolution of fetal MR images, whereas the ability of MR to visualize the whole fetus improves limited ultrasound views (32).

Although 2D and 4D US are able to detect many kinds of fetal brain malformation, some studies (33) have shown that 2D and 4D ultrasound detection rates of fetal brain anomalies are only about 40–50% which coincide with our data. Therefore the adjunctive use of MRI will increase the detection rate and quality assessment of fetal brain anomalies.

In vivo fetal MRI is the accurate adjunct tool to ultrasound to characterize brain malformation, to identify different causes responsible for brain damage, and to document mechanisms responsible for brain injury and their consequences on the developing brain (34).

## 5. Conclusion

Our results showed that fetal MR imaging is a useful modality in detection of fetal central nervous system anomalies as well as complementary modality to 2D/4D US in diagnosing fetal abnormalities in which US findings are inconclusive.

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